

Optical Limiting and Optical Bistable Devices With Fullerene Doped Aerogel/Xerogel Thin Films

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Purpose

Improve properties of fullerene composites for nonlinear optical (NLO) applications such as optical limiters and optical bistable devices by development of homogeneous molecular dispersion of fullerenes in porous silica aerogel and xerogel matrices.

transparency, and high thermal stability. The sol-gel composites will be converted to aerogels by replacing the solvent (ethanol) with air under supercritical conditions using liquid carbon dioxide, which preserves the delicate gel structure. Low-density xerogel will be produced during processing by using a series of aging and chemistry modification steps that reduce shrinkage during rapid drying at ambient pressure.

Background

Optical limiting and optical bistable phenomena are well established for liquid solutions of fullerenes (C_{60} and C_{70}); however, the incorporation of these materials into solid matrices such as polymers have resulted in poorer optical properties. This reduced performance is perhaps due to a lack of molecular dispersity. The goal of this project is to explore the prospect of overcoming this problem by the dispersion of fullerenes into aerogels and xerogels with pores less than 10 nm in size.

Silica aerogels and low-density xerogels prepared by sol-gel processing are promising matrix materials for NLO composites because of their unique properties such as small pore size,

Approach

Methods will be developed to improve NLO properties of fullerene composites compared to the corresponding liquid solutions by dispersing fullerenes at the molecular level in porous silica aerogel and low-density xerogel matrices. This will include the following tasks:

- Vary processing parameters during preparation of porous aerogels and xerogels to determine conditions that provide materials with small uniform pores for dispersion of fullerenes at the molecular level. Preparation of aerogels is being performed by D. Noever/ES76, L. Sibille/USRA, R. Cronise/ES76, and D. Smith/ES76.

- Incorporate fullerenes into the pores of aerogel and xerogel matrices to prepare NLO composites and examine their potential use for device applications such as optical limiters and optical bistable devices.
- Establish the relationship of NLO properties and chemical structure using atomic force microscopy, IR/Raman spectroscopy, and optical and nonlinear optical properties that include third-order optical nonlinearities, refractive index, optical limiting, and optical bistability.
- Perform initial studies of the effect of gravity using KC-135 and/or sounding rocket flights performed with the GOSMAR space hardware developed by 3M, which may require modification.
- Aerogel/vanadyl phthalocyanine silica gel composites were also prepared during the Conquest 1 sounding rocket flight. The light brown samples were transparent; however, they contained bubbles. Attempts to perform supercritical drying to prepare aerogels resulted in their destruction. The study of these composites will be included in this project because of the promising initial results, and they should exhibit good third-order optical nonlinearities, optical limiting, and optical bistability.

Preparation of Xerogel/C₆₀ Composites:

- High quality samples were prepared that contain varying amounts of C₆₀. These samples will be characterized by determining their NLO properties which will include optical limiting, optical bistability, and third-order optical nonlinearities.

Accomplishments

Initial Study of Microgravity Processing of Aerogel/C₆₀ and Aerogel/Phthalocyanine Composites:

- Six silica gel/C₆₀ samples were prepared by the sol-gel process during a flight of the Conquest 1 sounding rocket in April 1996 using the GOSMAR space hardware that was designed and built by 3M. Some samples were prepared using ethanol and water as solvents and others also contained dichlorobenzene to increase solubility of C₆₀. The low-gravity samples contained bubbles; however, an attempt was made to supercritically dry them in a large autoclave at Lawrence Berkeley National Laboratory in Berkeley, California. Four samples were lost due to a malfunction in the autoclave. The remaining samples were opaque and revealed that aggregation occurred during drying. This problem will be studied during ground-based studies. Low-gravity experiments may be performed in the future using KC-135 and/or short-duration rocket flights.

Follow-on Activity

- Based on this research, funding from NASA and other government agencies such as NSF and DARPA will be sought in the future. Collaborations will be established that will increase the participation of minorities in science, and especially involvement in NASA research programs.

Planned Future Work

- Continue ground-based study of the preparation of aerogel/C₆₀ composites and low-gravity studies using KC-135 and/or sounding rocket flights based on available opportunities.
- Characterize xerogel/C₆₀ composites prepared during the initial studies, and based on this, modify synthetic procedures to obtain composites with optimum properties.

- Expand this study to include the preparation of phthalocyanine doped aerogel/xerogel thin films for NLO and optical limiting applications. This will be carried out in collaboration with Dr. B.R. Reddy of the Physics Department at Alabama A&M University, and Angela Davis, an M.S. degree student.
- Follow-on activities will consist of seeking funding from NASA–RTOP, NSF, DARPA, and other agencies. Educational outreach that includes minority institutions will be established.

Publications

Hunt, A.; Sibille, L.; Cronise, R.; Noever, D.; Sunkara, H.; and Ayers, M.: “Silica Aerogel Meso-porosity: Short-duration Microgravity Results,” In Preparation, 1997.

Funding Summary (\$k)	
	FY97
Authorized:	10
Obligated:	10

Status of Investigation

Estimated completion date—End of FY98

To be continued in FY98 with additional funds of \$25k (to include salary for Laurent Sibille/USA for 10 percent of his time on project).